IMAGING TECHNOLOGY for the Icing Research Tunnel

National Aeronautics and Space Administration
Lewis Research Center

Imaging in Lewis' Icing Research Tunnel

NASA Lewis Research Center's Icing Research Tunnel (IRT) is the world's largest refrigerated wind tunnel dedicated to the study of aircraft icing. Lewis' oldest and busiest facility, the IRT was built at the end of World War II and has been ensuring flight safety in icing conditions ever since. It proved instrumental in the development and testing of ice protection systems for piston- and propeller-driven aircraft, and played a substantial role in the development, testing, and certification of methods to prevent ice buildup on gas-turbine-powered aircraft.

Since that time, the tunnel has been updated with a larger fan motor, improved fan blades, computerized tunnel controls, and electronic data acquisition, storage, and processing. Work continues today in the investigation of next-generation ice protection systems and certification of ice protection systems for military and commercial aircraft.

The IRT is a closed-return, atmospheric-type tunnel with a 5000-hp drive fan, a 2100-ton cooler, a water droplet spray bar, and a 300-mph test section. It can duplicate natural icing conditions at atmospheric pressure, producing continuous airspeeds from 50 to 400 mph and temperatures as low as –40 °F year-round, controllable to within one degree Fahrenheit. Supercooled water droplets between 15 and 270 μm, with water content controllable between 0.5 and 2.5g/m^3, can be produced to form an icing cloud. The 6-ft-high, 9-ft-wide, 20-ft-long test section can accommodate many full-sized aircraft components as well as large-scale models. A turntable allows models to rotate ±20° for various angles of attack.

Aircraft icing is a strikingly visual process. Often an imaging technique is the only way to record the most important features of an icing test. For this reason, a wide array of imaging systems and ways to use them are available to researchers conducting tests in the IRT. From 35-mm photography to high-speed motion analysis and infrared thermography, the techniques and services described here greatly increase the usefulness of Lewis' IRT.

Overview of Imaging Systems Available

Video and still photographic equipment are available for recording visual data and for documenting instrumentation. Photographic equipment can be mounted in or on the tunnel hatch, mounted in the control room windows, or carried into the test section between runs. If necessary, the hatch cover's acrylic windows can be replaced with other materials. Any required alterations to the hatch cover need to be discussed with the facility manager and IRT project engineer as far in advance of the test as is possible. Tunnel users must supply their own film and video tapes.

Imaging support is available from Lewis' Imaging Technology Center. Members of the Still Photo Group can document hardware, installation, and other aspects of tests. Specialists from the Scientific Imaging Group use a variety of imaging technologies to solve data-acquisition and analysis problems. They can provide technical assistance and advice for more complicated needs. We recommend that imaging requirements be discussed as early as possible during a project's planning stages to ensure the availability of systems and support.

The types of imaging available are described in the following sections: *Still Imaging*, *Digital Still Imaging*, *Video Imaging*, *High-Speed Imaging*, *Infrared Thermography*, and *Three-Dimensional Still Imaging*.

Still Imaging

Both Nikon F3 and F4 cameras are available with either a standard databack[1] or, if necessary, a 250-exposure databack. Both cameras are available with flash. With the Nikon F4, which has a continuous motor drive rate of 5 frames per second (fps), exposures can be as short as 1/8000 sec.

Depending on the needs of the test, the ambient lighting in the tunnel can include quartz halogen lamps with a color temperature of 3200K or HMI lighting with a color temperature of approximately 5500K (daylight). In most circumstances, flash is recommended.

Nikon F3 with on-camera flash.

Nikon F4 with on-camera flash.

The Nikon lenses available have focal lengths ranging from 35 to 400 mm. The 60-mm macro lens has been the most popular both for general overall shots and close-ups of icing details.

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[1] This feature allows exposures to be labeled with the time, date, or other information.

Digital Still Imaging

A Kodak Professional DCS 420 digital camera is available to facility customers during IRT experiments. The system consists of a Nikon N90 body and a special Kodak back. The DCS 420 can be used to capture single frames or a sequence of up to five images at a rate of about 2 fps. It can be used in conjunction with all of the camera's other functions: self-timing, different flash modes, and different light-metering options. The images can be stored in the memory unit or on a PCMIA III (Personal Computer Memory Card International Association) card. Thus, either commercially available hard disk cards or flash memory cards can be used to store the images.

The digital images produced by the Kodak DCS 420 have a resolution of 1524 by 1012 pixels with 36-bit color (12 bits per channel—red, blue, and green). The DCS system, which is powered by batteries, can capture up to 1000 images per full charge. An ac battery charger/adapter is included with the system. Users can transfer images from the DCS to a host computer by connecting it to a Macintosh or to a computer that supports Microsoft Windows.

Kodak Digital Camera System (DCS) 420 coupled with a Panasonic cf60 laptop displaying a closeup image of glaze ice.

Video Imaging

Several video cameras are available to IRT customers. These cameras, which operate at the standard rate of 30 fps, are available in both black & white and color. All take "C" mount lenses, but available adapters allow Nikon lenses to be used as well. The camera signals can be genlocked together if necessary.

All video camera control units, pan and tilt controls, video tape recorders, switching units, and monitors are rack mounted in the IRT control room. Up to eight monitors can display different views at the same time. In addition, a switcher can select any one of six different views to display on a large monitor. There are six decks that can record in either S–VHS or regular VHS formats. All video signals can have a time code inserted. This makes it easier to compare different views and tapes of the same event. A character generator is available for inserting text into the video to add titles or annotate run conditions. Finally, a Sony Still Video Printer is available. A switcher can divert any video signal into it for still frame capture and printing.

One of the video cameras available, a color Panasonic D5000, is mounted in the well above the test section to monitor the model for safety. If desired, the output of this camera can be recorded for use as data. Additional video cameras include Sony AVC–D7's, DXC–101's, and DXC–107's, a Xybion camera, and a Betacam. The high-resolution Sony AVC–D7's are small black & white cameras that, depending on lighting, can be gated down to 1/10,000 sec. Existing wiring allows these cameras to be placed in any test section window. Like the AVC–D7's, the Sony DXC–101 and DXC–107 color video cameras can be placed in any window. They are, however, lower in resolution. The Xybion camera has both extremely short-duration gating capabilities (10 nsec) and low light sensitivity.

The Betacam's capabilities include high resolution and high magnification, making it useful for closeups. In previous tests, this equipment has been used to document the accretion of ice in a very small area. Although the Betacam can record images in VHS or S–VHS format, users should record images in the Betacam format to realize the camera's high-resolution capabilities. Also, users should ensure that they have compatible devices for playing tapes made in the IRT.

High–Speed Imaging

For high-speed imaging, the IRT has two different Kodak Ektapro Motion Analysis systems. Both employ intensified imagers that can be gated to 10 µsec and that operate at 1000 fps. The resolution is lower than that of conventional video.

Both systems have an imager, a controller, and a processing unit. However, the Ektapro TR records data on special tapes, the total recording time available at 1000 fps is 30 sec, and synchronization with the event is crucial. In contrast, with the Ektapro EM system, the images are stored in electronic memory, at 1000 fps there is a 4.9-sec recording window, and because the system has a post-trigger mode, synchronization with the event is less critical.

The images captured by either system must be downloaded to a VCR if they are to be saved. If desired, single frames can be directed to the video printer. A final option involves having frames stored and analyzed by a computer. A member of the Scientific Imaging Group must assist in setting up and operating the Ektapros and their components.

Kodak Ektapro EM system intensified imager, control unit, processor, and monitor for high-speed (1000 fps) video.

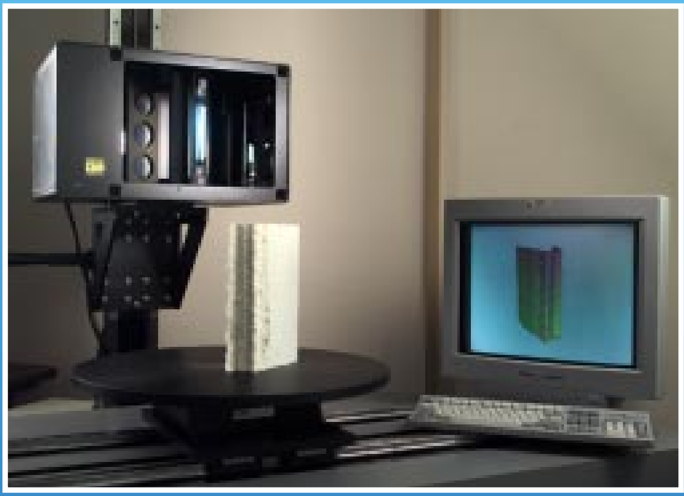
Infrared Thermography

A state-of-the-art AGEMA 900 long-wave infrared thermographic camera is available for IRT research. This powerful imaging system gives extremely high quality real-time thermographic images that allow extremely accurate measurement of surface temperatures. The data can consist of still images, sequences, time lapses, or temperature graphs of preselected areas of interest. The system cannot, however, easily view highly polished metal surfaces or through glass or plastic. Examples of the system's use include watching the temperature change associated with the impingement, runback, and freezing of water on an airfoil, monitoring deicing heater zone warming, and detecting the transition between laminar and turbulent air flow. Because of the complexity of the system, potential users must consult with the Scientific Imaging Group during the initial planning phase of the project. The topics discussed would be the type of data desired and what adaptations need to be made to the tunnel or model to ensure the accuracy of the data.

AGEMA 900 thermographic infrared video system. Image shows the temperature difference resulting from a boundary layer transitioning from laminar to turbulent flow on the upper surface of an airfoil.

Three–Dimensional Still Imaging

A three-dimensional still imaging system built by Cyberware is on hand at the IRT. It measures three-dimensional objects to a resolution as fine as 0.1 mm (depending on the axis of measurement). This laser-scanning imaging system resides in a cold room located just outside the diffuser section of the tunnel. Items to be scanned can be roughly as large as a 3-ft span of accreted ice. The model must be either (1) small enough to be moved by hand from the test section to the cold room, (2) built with a removable section, or (3) designed so that a section of ice can be removed, such as with a thin electrical heater. For further analysis, scanned, three-dimensional images can be postprocessed with Surfacer software running on a Silicon Graphics, Inc., Octane workstation. At the time of writing, this three-dimensional imaging equipment had been recently acquired. The full extent of its capabilities are still being explored. Call for updated details.



Cyberware three-dimensional scanner system with a cast model of glaze ice. The monitor displays the resulting image.

For more information, visit the IRT on the World Wide Web:
http://www.lerc.nasa.gov/WWW/IRT/

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